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# HIGH-TEMPERATURE VAPOR-FILLED THERMIONIC CONVERTER

QUARTERLY TECHNICAL PROGRESS REPORT
FOR THE PERIOD
OCTOBER 1 THROUGH DECEMBER 31, 1962

Contract AF 33(657)-8563
Project No. 8173, Task No. 817305-5

Aeronautical Systems Division
Air Force Systems Command
U. S. Air Force
Wright-Patterson Air Force Base, Ohio



January 7, 1963

GENERAL ATOMIC

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JOHN JAY HOPKINS LABORATORY FOR PURE AND APPLIED SCIENCE

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January 7, 1963

## FOREWARD

The work covered by this report was accomplished under Air Force Contract AF 33(657)-8563, but this report is being published and distributed prior to Air Force review. The publication of this report, therefore, does not constitute approval by the Air Force of the findings or conclusions contained herein. It is published for the exchange and stimulation of ideas.

## SUMMARY

During the reporting period Cell F was operated at power for 484 hours. Cell F, as noted in the monthly reports, is the first cell in which the expected current emission density has been observed from a carbide emitter in an engineered thermionic generator. Short-circuit currents of 120 amp were observed from the emitter in the cell. A maximum power output of 50 watts (5 $w/cm^2$) was obtained at an emitter temperature of 2440°K. During steady state operation power was in the range from 10 to 30 watts. The cell was not optimized for maximum power. The contact potential in the cell agrees with that expected from a low work function carbide emitter and a fully cesiated collector. For a nominal contact potential of 1 volt and a short-circuit current of 120 amp, the optimum power should have been 120 watts, assuming no transport defects in the cell. Actually the maximum power output corresponding to a short-circuit current of 120 amp was more nearly 40 watts, indicating transport defects in the cell. The spacing in Cell F is 20 mils. It is proposed that a reduced spacing be used for succeeding generators to obtain a better correspondence between predicted and observed power. The principal significance of the test remains, however, the performance of the emitter itself.

The task of fully optimizing the generators to take advantage of this emitter performance is likely to be a more gradual one. Optimization of the temperature of the cesium reservoir and of the collector jointly was not established. A considerable amount of data has been obtained on the separate effects of the cesium reservoir temperature and of the collector temperatures from which optimum power can be estimated. However, frequent filament failures during operation have interfered with plans to complete systematic optimization of all cell operating parameters. The

data indicate an optimum cesium temperature of 625°K. A trend of increasing power output with decreasing collector temperature to 875°K was noted with constant emitter and cesium temperatures.

During the last month of this quarter the power output of Cell F had decreased to such an extent that it is planned to terminate this test after Cell G becomes operable. It is unknown at this time what the cause of decreased power output is. It appears that the quantity of cesium present in the cell is insufficient to maintain the required cesium density in the vapor phase.

The construction of Cell G has been in progress during this reporting period and completion was scheduled during the period. A succession of leaks in the insulator, which first appeared in mid-December, has delayed the schedule. Also, during the final phase of Cell G construction, a short between the emitter and collector was discovered, necessitating a major repair.

Cell bases H and J have been completed and baked out. Emitter No. 39 showed a satisfactory vacuum emission (1 amp/cm$^2$ at 2200°K). The emitter has been welded into the cell structure subsequent to the emission trials.

The development of higher UC-content emitters has been terminated. Fabrication of 10 UC - 90 ZrC emitters continues as required by the test program.

The microprobe analysis of the Mark V-E emitter has been received. This completes the post-test analysis of the Mark V-E Cell.

The study and evaluation of fission products was initiated in December.

During the next month the operation of Cells G and H is scheduled. Cell J will be completed as a stand-by unit. When Cells G and H become operational, series and parallel operation are planned.

# GENERAL

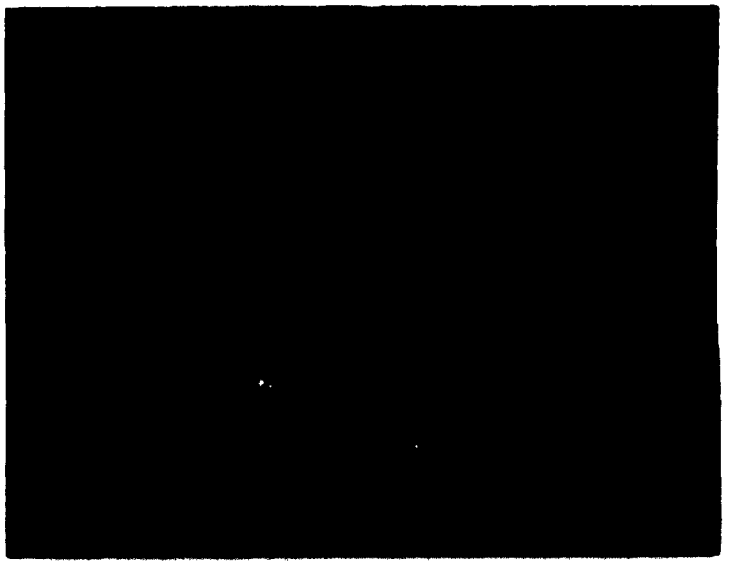
## CELL F

During the previous quarter, an emitter (No. 28 with 10 UC - 90 ZrC composition) had indicated satisfactory vacuum emission at temperatures up to 1700°K, the temperature at which the low-current power supply became current-limited. This emitter was electron-beam welded into Cell F. The emitter was heated to 2000°K ± 30°K for a period of 40 hours, a standard procedure to age the emitter.

Using the recently delivered 5-kv (50-amp) power supply, data were taken for a number of different emitter temperatures. Vacuum emission currents up to 5.8 amp/cm$^2$ at 4 kv and 2200°K (corrected pyrometer reading) were observed. A representative waveform for an emitter temperature of 1883°K is shown in Fig. 1. The observed current densities were plotted as a function of emitter temperature as shown in Fig. 2. These values were still slightly lower than the best values obtained on small discs (see GACD-3389); however, it should be pointed out that the temperature distribution over the entire emitter varies by perhaps 100°K and the data are evaluated on the basis of the highest temperature observed.

Thermocouple calibration was conducted simultaneously with the vacuum emission studies. The thermocouples were then vacuum-brazed into Cell F, and the collector was electron-beam welded to the cell.

On November 2, 1962, Cell F was installed in the bell jar and attached to the external Vac-Ion pump through a flanged connection near the base plate. At this point two vacuum emission runs were made to evaluate the emitter condition. After cooling, the Vac-Ion gauge showed a vacuum of $10^{-9}$ at the pump location (about 2 feet from the cell). The pump-out connection was pinched off and seal welded. During pinchoff



DATE: 10-23-62

Abscissa: 0.5 kv/div

Ordinate: 2 v/div (obtains 2 amp/div across 1-ohm resistor)

Current: 7.8 amp at 4 kv applied voltage

Emitter temperature: 1883°K

Emitter: No. 28

Fig. 1--Representative waveform of emission current as a function of applied cell voltage

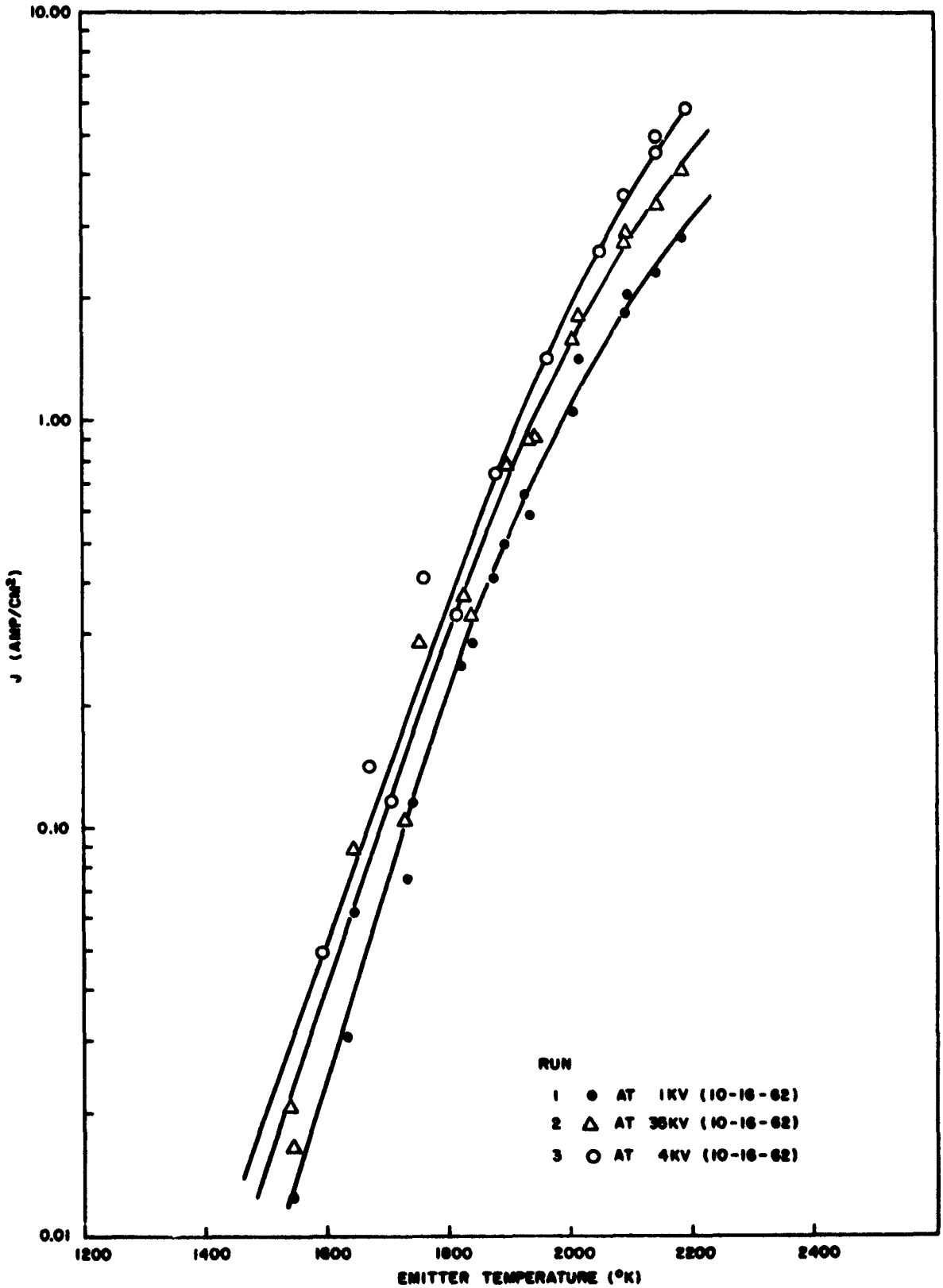



Fig. 2--Vacuum emission of emitter No. 28

the opposite end (still connected to the Vac-Ion pump) showed a slight momentary increase in pressure followed by an almost immediate recovery to its original value, indicating a successful operation. The completed cell is shown in Fig. 3.

After cell isolation from the Vac-Ion pump a final vacuum emission run was made. The results of this test and one previous test are shown in Fig. 4; they are comparable to the original data taken before cell closure. On November 7, cesium was introduced into the cell, external thermocouples were installed, and operation commenced.

On November 17, a filament burned out after 181 hours of operation. During the filament replacement, repair of a leak in a cooling system line was also made. On November 23, a second filament failure occurred. When the filament holder was removed, ~3/4 inch was badly eroded near the filament. On November 25, a similar occurrence prevented further operation. Two additional filament failures have occurred, all presenting the same symptoms.

The erosion problem near the tip of the filament holder has not yet been solved. It has been established that the emitter stem inside diameter has been reduced by ~30 mils due to deposited tantalum from the eroded section. Mere replacement of the present filament holder and filament was impractical in view of the decrease in cavity size. A spectrographic analysis of the filament holder at the eroded section indicated small amounts of magnesium, aluminum, and silicon with traces of other impurities. It was speculated that the sources of the major contaminants were reaction products either from the lavite insulator at the base of the filament holder or the alumina insulator near the top with the tantalum filament holder. It was thought that the above impurities were not released effectively until the emitter reached a relatively high temperature. However, concurrent with their release, the high-current electrom bombardment power tended to set up a positive ion bombardment of the

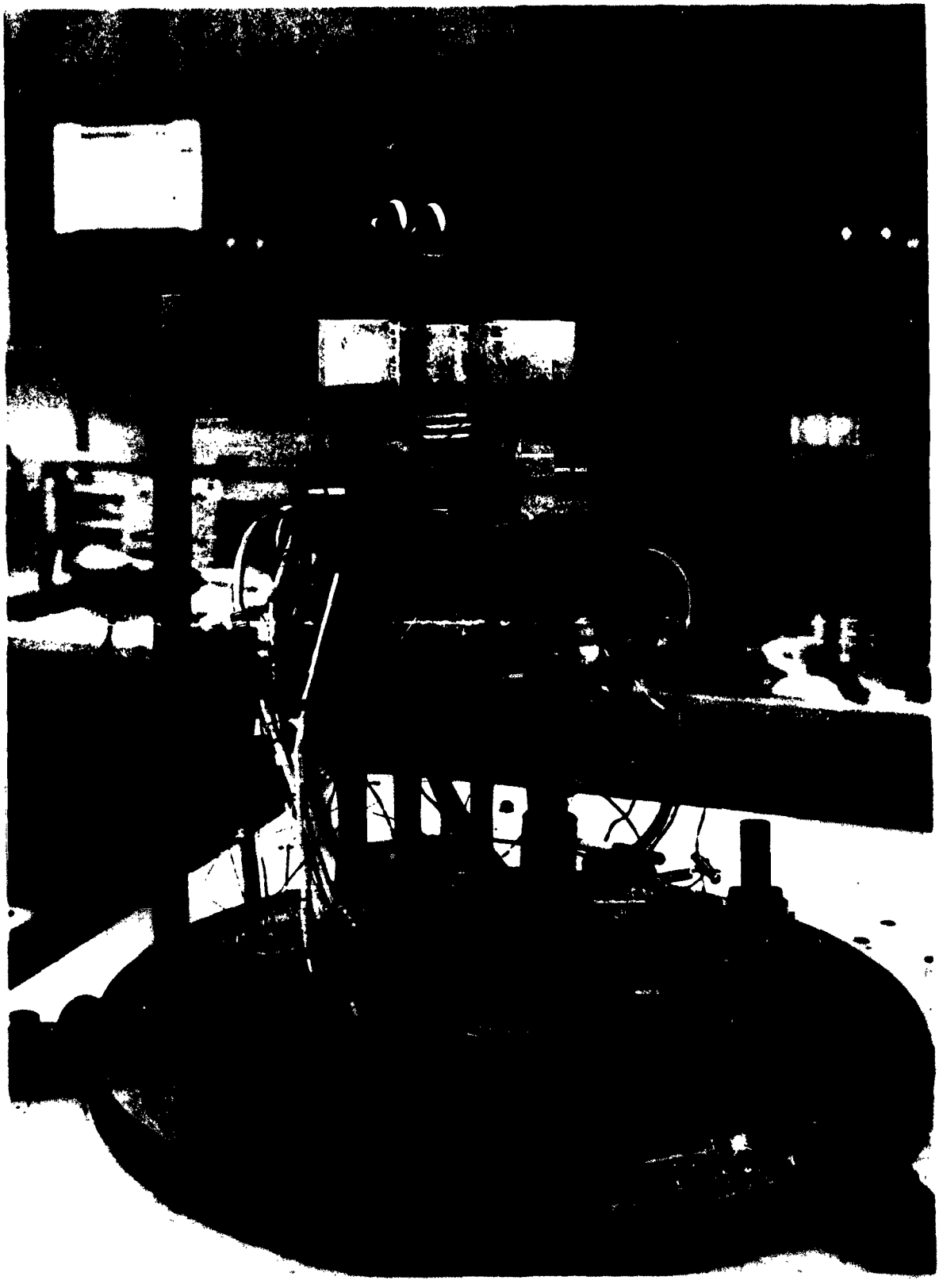


Fig. 3--Cell F

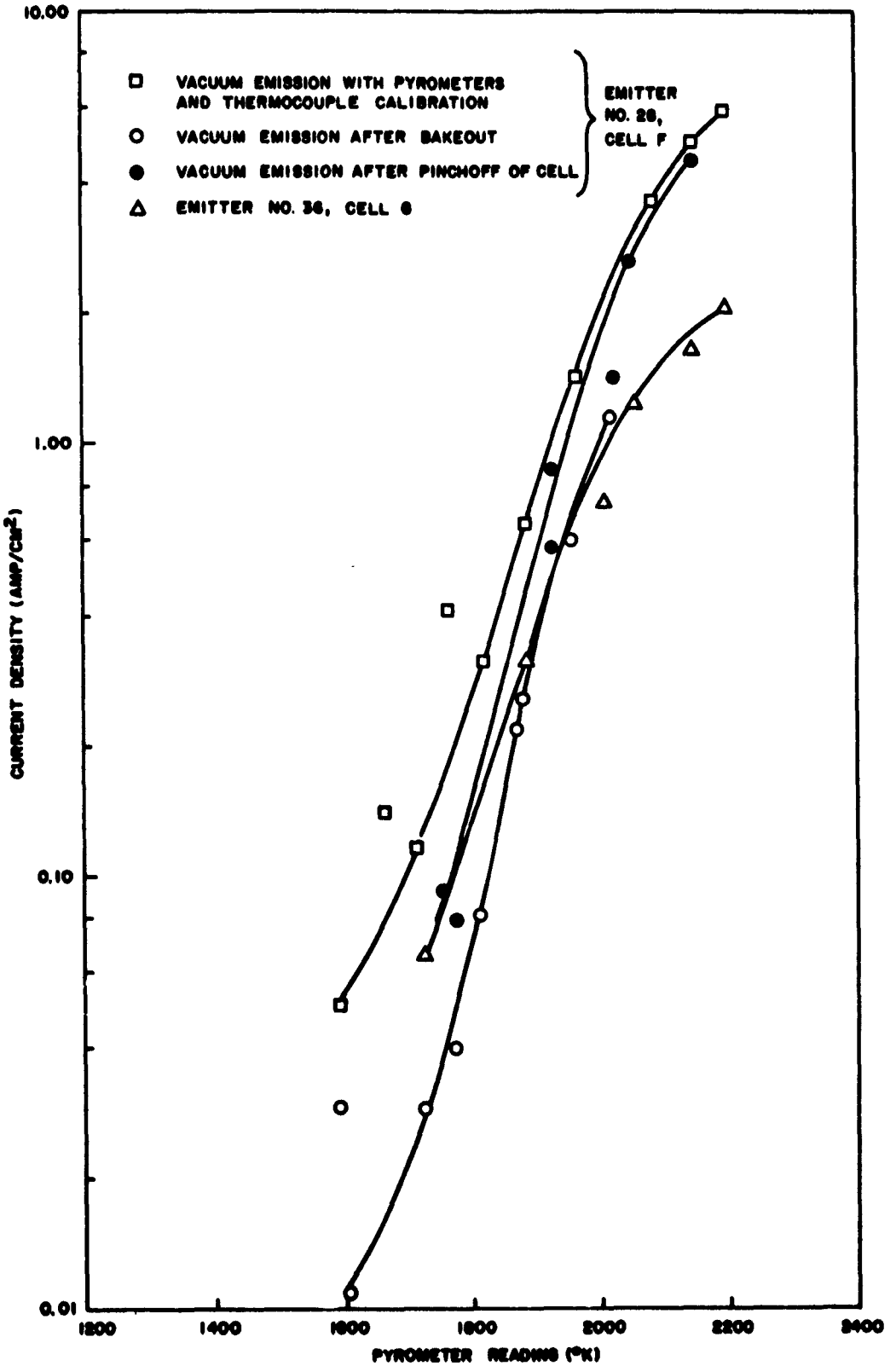



Fig. 4--Results of final vacuum emission test

filament stem. Consequently two bakeout periods were undertaken at emitter temperatures of ~400°C and ~1500°C. At this low level of cell power it was speculated that the greatest net reduction in impurity level would occur.

This procedure has not been successful. One filament lasted 4.3 hours while another survived nearly 50 hours of operation at power.

While the entire cause of the filament failure is not known, the following are believed to be possible contributing factors:

(1) The small insulator mentioned above was not of the same high-purity alumina as had been used previously.

(2) A lavite-base insulator (not baked out at high temperature in vacuum) was used as filament support.

(3) A tantalum-filament holder instead of the original molybdenum holder was used (at high temperature reactions between tantalum and alumina occur).

(4) The filament holder reached excessively high temperatures.

(5) There was a possibility of a cesium-to-filament cavity leak.

To minimize the filament burnout problem, the following changes have been made:

(1) The small insulator was moved into a lower temperature region.

(2) High-purity alumina is being used.

(3) The lavite insulators were discarded.

(4) Molybdenum filament holders will be used.

(5) Openings were made into the holders to facilitate evacuating the emitter cavity.

During the first 10 days of operation the effect of cesium pressure was studied. Data were obtained over a cesium temperature range of 473 to 650°K and emitter temperature range of 1700 to 2200°K. The collector temperature was allowed to float, the only cooling provision being a heat radiator. The maximum collector temperature observed was 1170°K. The cesium temperature was increased stepwise from 470°K to 660°K in order to bracket the optimum cesium pressure range very early in the program. In order to assure reasonable cesium pressure equilibrium within the cell, the cesium temperature was raised about mid-day, a set of data taken, and then the cell allowed to operate with a constant load. Voltage and current were recorded continuously except during periods of data taking. The following morning a second set of data was obtained at the same cell conditions existing the previous afternoon and then the cesium temperature was increased. Analysis of the recorded power data indicated that the cell reaches cesium pressure equilibrium within a very short time (< 30 minutes). During this period, it was fairly well established that the optimum cesium temperature was between 575 and 625°K for maximum power output. In Fig. 5 a family of curves is presented indicating cell performance as a function of emitter temperature at several cesium temperatures. The amount of data obtained to date at controlled conditions is insufficient to establish optimum cesium pressure uniquely. When the effect of collector temperature is evaluated, it will be possible to evaluate the effect of cesium pressure.

Raw data for two days of cell operation, December 1 and December 11, are shown in Table 1. Oscilloscope traces corresponding to some of these data are shown in Fig. 6A and 6B (note power decrease in December 11 data).

During the intermittent operation since November 17, an effort has been made to determine the optimum collector temperature. A cooling ring was mounted on the collector above the radiator and was connected

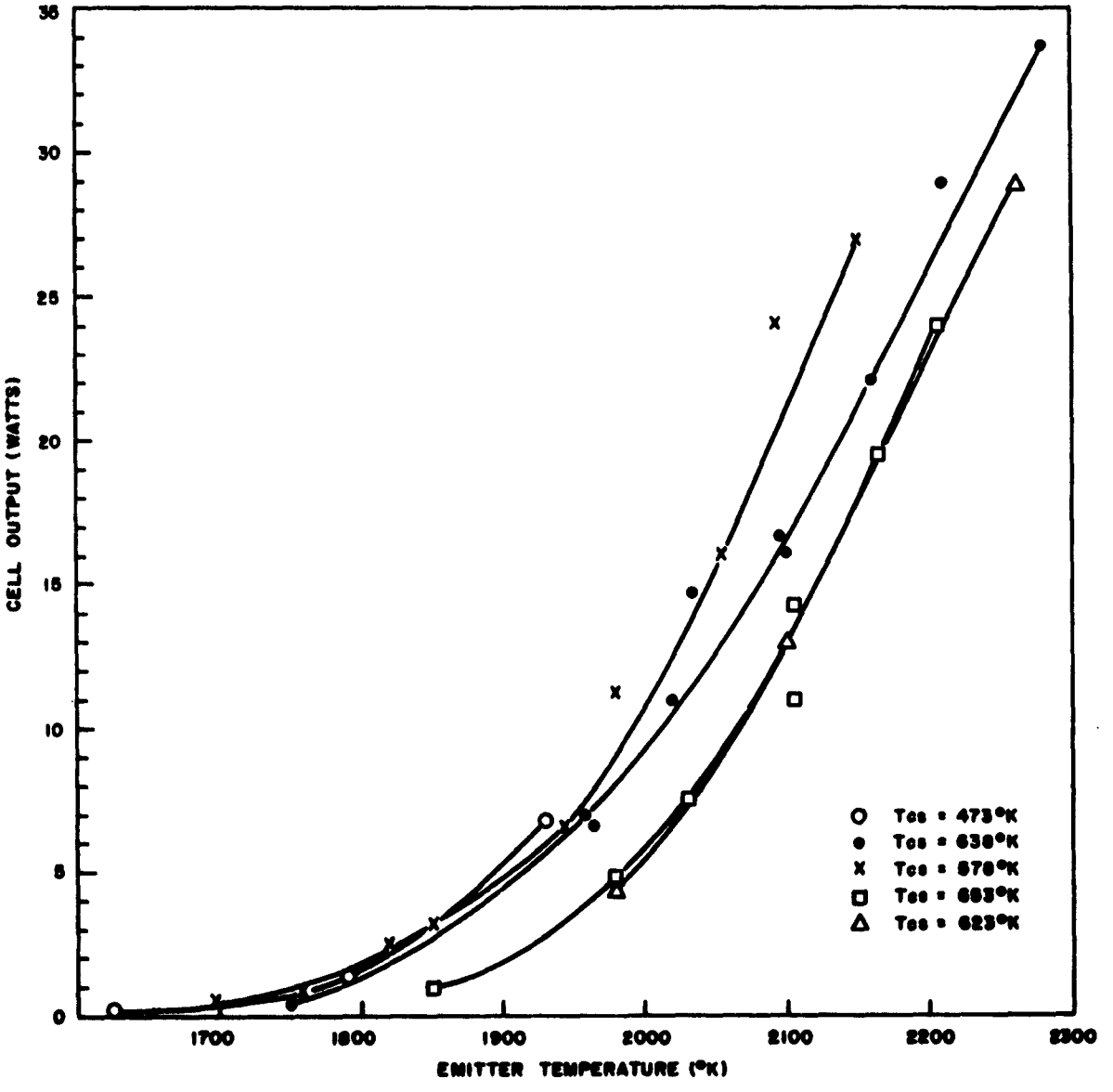
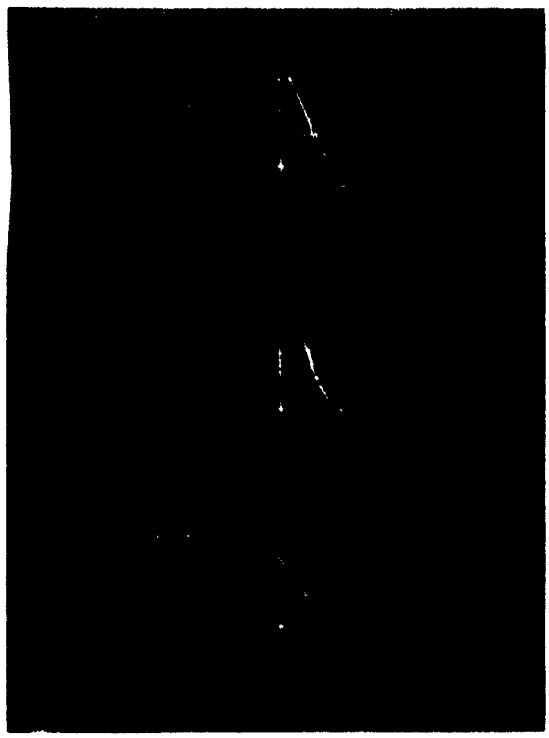



Fig. 5--Cell performance as a function of emitter temperature at several cesium temperatures

## Table 1. Data from two days of cell operation

| Time | Power Input | | | | | Emitter Thermocouple No. 2 | | Temperatures °C | | | Cell Output | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Filament | | Bombardment | | | | | | | | | | |
| 12-1-62 | Volts | Amps | Volts | Amps | Total Watts | Millivolts | °K | Cesium Well (No. 1) | Insulator (No. 5) | Collector (No. 12) | Open Circuit Voltage Volts | Short Circuit Current Amps | Photo No. |
| 0946 | 6.75 | 15.2 | 382 | 1.64 | 729 | 23.12 | 2025 | 284 | 398 | 712 | | | |
| 1015 | 6.80 | 15.0 | 335 | 1.92 | 747 | 23.98 | 2070 | 302 | 410 | 730 | (0.26) | 58.0 | 97 (a) |
| 1027 | 6.82 | 14.8 | 305 | 2.27 | 793 | 25.41 | 2154 | 302 | 415 | 752 | (0.20) | 72.0 | 97 (b) - (c) |
| 1037 | 6.88 | 14.6 | 290 | 2.50 | 825 | 26.11 | 2190 | 310 | 420 | 770 | (0.20) | 76.0 | 98 (a) |
| 1045 | 6.88 | 14.6 | 305 | 2.18 | 765 | 24.95 | 2130 | 312 | 422 | 765 | | 60.0 | 98 (b) |
| 1100 | 6.85 | 14.8 | 365 | 1.40 | 612 | 21.31 | 1815 | 315 | 410 | 680 | | 25.0 | 98 (c) |
| 1121 | 6.70 | 14.4 | 410 | 1.42 | 679 | 22.51 | 1990 | 310 | 407 | 685 | | 38.0 | |
| 1145 | 7.00 | 14.6 | 332 | 1.88 | 673 | 23.82 | | 307 | 412 | 730 | | | |
| 1530 | 7.50 | 12.7 | 275 | 2.25 | 714 | 24.43 | | 355 | 427 | 741 | | | |
| 12-11-62 | | | | | | | | | | | | | |
| 1345 | 6.20 | 15.1 | 420 | 1.50 | 724 | 23.70 | 2060 | 301 | 404 | 725 | 1.65 | 3.20 | |
| 1355 | 6.20 | 15.0 | 395 | 1.64 | 741 | 24.45 | 2100 | 305 | 406 | 740 | 1.62 | 3.40 | 103 (a) |
| 1403 | 6.15 | 15.3 | 482 | 0.95 | 560 | 21.10 | 1915 | 307 | 405 | 690 | 1.38 | 0.52 | 103 (b) |
| 1416 | 6.20 | 14.8 | 400 | 1.70 | 772 | 25.10 | 2135 | 309 | 406 | 740 | 1.64 | 3.80 | 103 (c) |
| 1426 | 6.20 | 14.6 | 360 | 2.00 | 810 | 26.10 | 2192 | 310 | 410 | 770 | 1.60 | 5.60 | 104 (a) |
| 1435 | 6.20 | 14.6 | 335 | 2.24 | 841 | 26.70 | 2225 | 312 | 411 | 785 | 1.58 | 7.20 | 104 (b) |
| 1445 | 6.25 | 14.5 | 306 | 2.54 | 868 | 27.50 | 2270 | 315 | 415 | 815 | 1.55 | 9.40 | 104 (c) |
| 1508 | 6.20 | 14.5 | 360 | 1.90 | 775 | 25.50 | 2160 | 320 | 405 | 782 | | | |
| | | | Increasing Cs Temperature | | | | | | | | | | |
| 1549 | 6.25 | 14.5 | 355 | 1.96 | 786 | 25.70 | 2170 | 350 | 416 | 783 | 1.53 | 6.0 | |
| 1601 | 6.25 | 14.4 | 328 | 2.25 | 830 | 26.70 | 2230 | 352 | 420 | 806 | 1.52 | 8.2 | |
| 1605 | 6.3 | 14.3 | 310 | 2.47 | 855 | 27.20 | 2255 | 352 | 420 | 815 | 1.52 | 10.0 | |
| 1610 | 6.3 | 14.2 | 285 | 2.85 | 899 | 28.00 | 2300 | 352 | 424 | 830 | 1.52 | 12.5 | |
| 1615 | 6.2 | 14.6 | 400 | 1.50 | 691 | 24.00 | 2080 | 355 | 425 | 780 | 1.40 | 4.0 | |

Photo No. 97



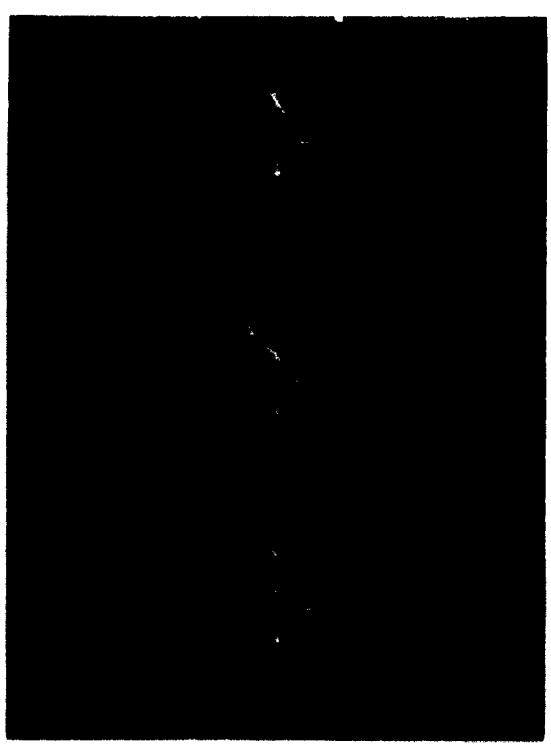
(a) Ordinate: 20 amp/div (1 v/div across 0.05 Ω). Abscissa: 1 v/div. $T_{Cs}$ = 575°K. $T_E$ = 2070°K.
Max. cell output: 30.8 watts (0.7 v at 44 amp).

(b) Ordinate: 20 amp/div (1 v/div across 0.05 Ω). Abscissa: 1 v/div. $T_{Cs}$ = 575°K. $T_E$ = 2154°K.
Max. cell output: 38.4 watts (0.8 v at 48 amp).

(c) Ordinate: 40 amp/div (2 v/div across 0.05 Ω). Abscissa: 1 v/div. $T_{Cs}$ = 575°K. $T_E$ = 2154°K.
Max. cell output: 38.4 watts (0.8 v at 48 amp).

December 1, 1962

Photo No. 98



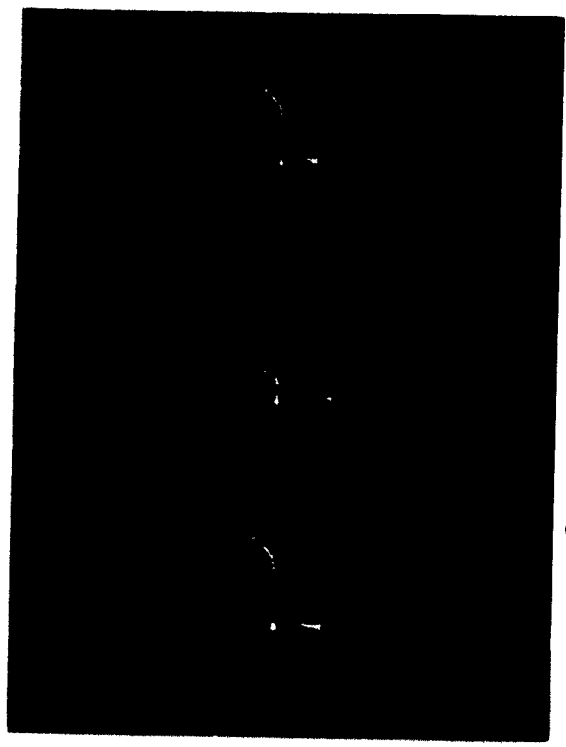
(a) Ordinate: 40 amp/div (2 v/div across 0.05 Ω). Abscissa: 1 v/div. $T_{Cs}$ = 583°K. $T_E$ = 2190°K.
Max. cell output: 39.6 watts (0.6 v at 66 amp).

(b) Ordinate: 40 amp/div (2 v/div across 0.05 Ω). Abscissa: 1 v/div. $T_{Cs}$ = 585°K. $T_E$ = 2130°K.
Max. cell output: 35.2 watts (0.8 v at 44 amp).

(c) Ordinate: 10 amp/div (0.5 v/div across 0.05 Ω). Abscissa: 1 v/div. $T_{Cs}$ = 588°K. $T_E$ = 1815°K.
Max. cell output: 15.2 watts (0.8 v at 19 amp).

Fig. 6A--Oscilloscope traces showing cell performance

Photo No. 103



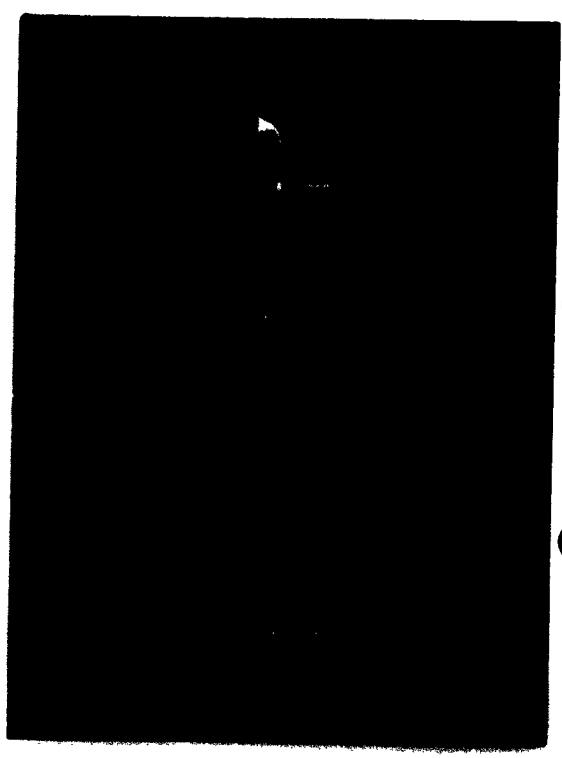
(a) Ordinate: 2 amp/div (0.1 v/div across 0.05 Ω). Abscissa: 1 v/div. $T_{Cs}$ = 578°K. $T_E$ = 2100°K. Max. cell output: 0.54 watts (0.3 v at 1.8 amp).

(b) Ordinate: 1 amp/div (0.05 v/div across 0.05 Ω). Abscissa: 1 v/div. $T_{Cs}$ = 580°K. $T_E$ = 1915°K. Max. cell output: 0.06 watts (0.3 v at 0.2 amp).

(c) Ordinate: 2 amp/div (0.1 v/div across 0.05 Ω). Abscissa: 1 v/div. $T_{Cs}$ = 582°K. $T_E$ = 2135°K. Max. cell output: 0.72 watts (0.3 v at 2.4 amp).

December 11, 1962

Photo No. 104



(a) Ordinate: 4 amp/div (0.2 v/div across 0.05 Ω). Abscissa: 1 v/div. $T_{Cs}$ = 583°K. $T_E$ = 2192°K. Max. cell output: 1.2 watts (0.3 v at 4 amp).

(b) Ordinate: 4 amp/div (0.2 v/div across 0.05 Ω). Abscissa: 1 v/div. $T_{Cs}$ = 585°K. $T_E$ = 2225°K. Max. cell output: 1.44 watts (0.3 v at 4.8 amp).

(c) Ordinate: 4 amp/div (0.2 v/div across 0.05 Ω). Abscissa: 1 v/div. $T_{Cs}$ = 588°K. $T_E$ = 2270°K. Max. cell output: 1.8 watts (0.3 v at 6 amp).

**Fig. 6B--Oscilloscope traces showing cell performance**

to the Dowtherm cooling system. Collector temperatures of 850°K to 1050°K have been studied at a cesium temperature of 578°K and emitter temperatures of 1700 to 2200°K. In Fig. 7 the results of this preliminary survey are presented for an emitter temperature of 1762°K and a cesium temperature of 578°K. The data indicate that with increasing collector temperature the cell power is decreased. The decrease in power with increasing collector temperature is presumedly caused by either increased back emission or poorer cesium wetting of the collector.

Thermocouple No. 2 is still operating reliably, although slightly higher power input is required to obtain the same emitter temperature. The cell output, however, has decreased for the same conditions. There is every indication that the cesium pressure in the cell is diminishing. The cell and the cesium well temperature was increased to 693° - 743°K which resulted in an increased power output. It is possible that the cesium vapor is no longer in equilibrium with cesium liquid and sufficient cesium pressure is only obtained at higher temperatures. While the maximum power output during this month was 41 watts at 2190°K and a cesium temperature of 575°K, the cell was operated during off-shift hours at approximately 10 watts. A total of 484 hours at power has been accumulated on Cell F.

## CELL G

Emitter No. 36 was welded into Cell G and has been fitted with a collector sized to obtain a 12-mil radial gap at operating conditions. The top of the emitter will be spaced about 70 mils from the mating collector surface to prevent shorting because of thermal expansion. Consequently, the top surface ($\sim 2$ cm$^2$) will not be an effective emitting surface.

Two thermocouples were temporarily inserted in the emitter for calibration and vacuum emission measurements. Both couples performed satisfactorily during calibration; but, during brazing and subsequent

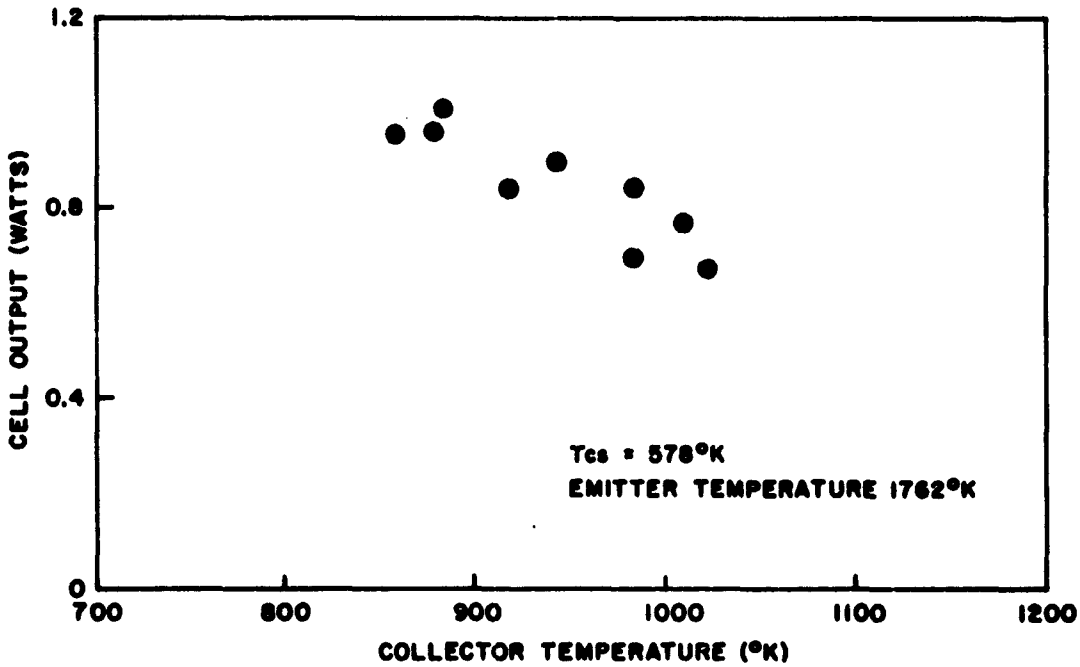



Fig. 7--Preliminary survey of optimum collector temperature ($T_E = 1762^{\circ}K$, $T_{Cs} = 578^{\circ}K$)

testing, one failed at the hot junction and the sheath failed on the second. Two new thermocouples were prepared for cell calibration and emission measurements. Each was fitted with a copper collar welded to the sheath which can then be sealed into the cell structure by heliarc welding in a purified inert gas atmosphere. This approach precludes the need for filament brazing of the thermocouples into the cell which has proved to be a time-consuming and unreliable process.

Three vacuum emission runs and a final temperature calibration check of the thermocouples were conducted on emitter No. 36. The collector was welded to the cell and the assembly baked out at ~425°C. The emitter was heated to 1700°K. The final check indicated a leak in the monel-to-copper weld at the lower side of the insulator. After each repair the assembly was leak tight but started leaking again after some thermal cycling. When the repaired joint survived an overnight bakeout, it was found that the collector had shorted to the emitter due to warping of either the insulator or the cell base. Repair of the short in Cell G is in progress.

## OTHER CELLS

Cell bases H and J were both completed and baked out. However, both developed leaks in the weld between the monel ring of the insulator and the copper cell structure. These welds have been repaired successfully.

Vacuum emission was measured for emitter No. 39 (10 UC - 90 ZrC) which was subsequently welded into a cell base at the end of the reporting period.

While Cell F had an emitter-collector spacing of 0.020 inch, Cell G is built with 0.011 to 0.013 and H will have 0.010 to 0.012 spacing. It is anticipated that two cells will be in operation in the next reporting period. At that time parallel and seriesed cell operation will be attempted.

## THERMOCOUPLE PROBLEMS

During the various vacuum emission studies, bakeout period, and final brazing of thermocouples to cell bases, frequent failures of the thermocouples occurred. While one thermocouple had an intermittent break of the sensor wires, all the other failures were due to failure of the tantalum sheath.

It was postulated that the tantalum sheath was filled with nitrogen and oxygen from the atmosphere prior to the forming of the hot junction. Either during hot-junction fabrication or during subsequent operation at elevated temperatures the tantalum sheath at the hot end would getter these impurities and become extremely brittle. Failure would then occur during thermal cycling. Self-welding of the sheath to the tantalum emitter slug may also contribute to these failures.

The following steps have been undertaken to reduce thermocouple failures:

(1) Thermocouples are baked out at 450°C in vacuum for 24 hours.

(2) After cooling, the thermocouples are filled with argon.

(3) The cold junction is sealed with an epoxy to trap the argon.

(4) Molybdenum foil 0.001-inch thick is wrapped around the thermocouple to prevent self-welding of the thermocouple to the emitter.

## EMITTER FABRICATION AND DEVELOPMENT

During October and November development on the fabrication of high uranium content carbide emitters on a metal substrate proceeded along two lines: (1) building a thin tungsten tube by chemical vapor deposition within the carbide emitter, and (2) plasma-arc spraying thin layers of carbides with graded composition onto a tungsten tube or onto

a tantalum tube coated with a barrier layer to prevent undesirable interaction.

The first of these techniques was tried with the aid of San Fernando Laboratory, Pacoima, California. Samples of nominal composition 30 mol-% UC - 90 mol-% ZrC were supplied to this laboratory for initial studies. All of the samples prepared for tungsten vapor deposition cracked during cooling because of the large difference in thermal expansion.

The investigation of plasma-arc spraying of a graded carbide structure on a metal substrate has been terminated due to excessive costs and a prohibitive schedule.

In the latter part of November it was decided to discontinue both developmental efforts on higher UC content emitters since neither approach was likely to yield useful hardware within the current contractual period.

In order to logically conclude the work on higher UC emitters, vacuum emission studies were conducted on emitter No. 33 (30 UC - 70 ZrC). The studies showed good vacuum emission currents; however, this emitter was not welded into a cell base. Based on the high uranium loss observed in earlier thermal-cyling runs of 30 UC - 70 ZrC emitters, it is not believed that sufficient hours of satisfactory operation can be anticipated. Subsequent cells will have 10 UC - 90 ZrC emitters.

During the reporting period seven 10 UC - 90 ZrC emitters were fabricated. Two of the first four emitters showed acceptable vacuum emission current and were subsequently installed in Cells F and G. The remaining three emitters are currently undergoing final machining.

## POST-OPERATION ANALYSIS OF MARK V-E EMITTER

Post-operation analysis of the emitter in the Mark V-E cell has now been completed. The results of electron-microprobe analyses which

have been performed can be summarized as follows*:

(1) The clear areas in the tantalum teeth immediately adjacent to the carbide are tantalum-uranium solid solutions containing about 3 wt-% uranium.

(2) Neither uranium nor zirconium have penetrated into the tantalum beyond these clear areas.

(3) The uranium content in the carbide is non-uniform, with the maximum value being 15 wt-% and the average value being 3 to 4 wt-%.

(4) Tantalum has penetrated fairly uniformly throughout the carbide at a level of about 6 wt-%.

(5) A very fine dispersion of small particles in the carbide was observed to be primarily tungsten or possibly tungsten carbide.

The major point to be noted is the large reduction in the uranium content of the carbide; i.e., from an initial content of 19.67 wt-% uranium to a final value of 3 to 4 wt-% uranium.

## FISSION FRAGMENT EFFECTS

Studies of the chemistry of the various fission products were initiated during the reporting period. It appears that the following fission product elements will tend to be released from bare carbide fuel materials to a degree dependent on time, temperature, and their diffusivity and volatility:

Electronegative - Se, Sb, Te, Br, I

Electropositive - Rb, Cs, Sr, Ba, Sm, Eu, Cd.

*References to structures relate to the microstructure illustrated in Fig. 2 of GA-3562 (Rev.).

It is also possible that some of the less volatile fission products (Y, Pd, Ag, In, Sn, La, Ce, Pr, Nd, Pm) may be released to some extent. Of these the most important are those underlined since they have fission yields > 0.3%.

A literature survey is underway to determine the fate of the fission products exposed to a highly concentrated cesium environment. The study of the interaction of fission products with each other and with the cesium vapor will aid in analyzing the subsequent reactions with the emitter and collector materials. A particular area worthy of consideration is the effect of deposited alkaline earth and rare earth fission products and fission product compounds ($BaI_2$, SrTe, BrTe) on the collector work function.

It is recognized that an analytical study of the fission product problem would not yield definitive design information; however, the results of this study should provide the basis for a future experimental program. No experimental work on fission product reactions is planned under the current contract.